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BRUCE NGS "B" STRESS MEASUREMENTS
CO-OPERATIVE PILOT PROJECT - FINAL REPORT

Report No 89-156-K

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Abstract

This report outlines the results of six of the rock stress measurements at Bruce NGS "B". The tests were carried out during June 27 - 30, 1988 in borehole US-6 as part of a co-operative project co-funded by Civil Engineering and Architecture and the Civil Research Department of the Research Division.

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To Dr. C.F. Lee
Manager
Civil Engineering & Architecture Department
H15A15

BRUCE NGS "B" STRESS MEASUREMENT
CO-OPERATIVE PILOT PROJECT - FINAL REPORT

1.0 INTRODUCTION

During the 1987 field exploration program on the proposed underground storage site, it was planned to perform 5 or 6 overcoring tests using the United States Bureau of Mines Borehole Deformation Gauge (USBM gauge). This series of tests was not carried out as planned because unexpected drilling conditions caused project delays which extended the project past the time window slotted for this project. The equipment and personnel assigned to the Bruce stress measurement project were previously committed to another long-term project whose schedule could not be altered and so it was decided to delay this project until the 1988 field season.

The purpose of this study was to determine whether there are high stresses existing in the rock units beneath the site. The units were determined by the Civil Engineering and Architecture Department to be tight and of excellent quality. It has been proposed to build an underground storage cavern in these rock units. The stress test results were to be used in the design of this cavern. The project was carried out in June 1988 and the initial results were released in July 1988 (1).

2.0 FIELD PROGRAM

The field program was directed by the Civil Engineering and Architecture Department and consisted of drilling two HQ3 (96 mm) diameter boreholes to a depth of approximately 300 feet (91 m). The purpose of these two boreholes, US-5 and US-6, was to obtain information on the rock formations adjacent to the proposed storage cavern site as is shown in Figure 1. Based on previous drilling information in the area, Mr. J.D. Grass of the Civil Engineering and Architecture Department recommended that the overcore testing be carried out in borehole US-6 as there was a greater probability that geologic horizons suitable for testing would be encountered.

3.0 TEST METHOD

A three component USBM stress gauge that measures the deformation of a pilot hole in three directions in a plane perpendicular to the borehole axis while it is overcored by a larger core bit was used in this study. The strains measured and the Young's modulus value determined in a biaxial test are combined in a formula based on a plane-strain analysis. The stresses contained in this report are the major secondary principal stress, P, and the minor secondary principal stress, Q. Past laboratory testing has shown these results to be within 15 per cent of applied loads. These stresses are termed secondary principal stresses as they represent only one plane in a three-dimensional body. Three non-parallel boreholes would be required to determine the complete stress field in a solid body.

This method has been found to be the most useful for in situ stress measurements for the following reasons:

1. Unlike the epoxy bond gauges, this method does not depend on obtaining a clean dry borehole.

2. The gauge is accurate, robust, and reliable.

3. The time required for a test is relatively brief compared to other test methods.

The formulae used in this analysis are:

$$P = -\frac{E}{6d(1-\gamma^2)}\left(U_1+U_2+U_3\right) + \frac{1}{\sqrt{2}}\left[(U_1-U_2)^2 + (U_2-U_3)^2 + (U_3-U_1)^2\right]^{1/2}$$

$$Q = -\frac{E}{6d(1-\gamma^2)}\left(U_1+U_2+U_3\right) - \frac{1}{\sqrt{2}}\left[(U_1-U_2)^2 + (U_2-U_3)^2 + (U_3-U_1)^2\right]^{1/2}$$

$$\theta = 1/2 \tan^{-1}\left(\frac{\sqrt{3}\,(U_2-U_3)}{2U_1-U_2-U_3}\right)$$

where P - major secondary principal stress

Q - minor secondary principal stress

θ - the angle between U_1 and P turned in a counterclockwise direction from U_1

E - the Young's modulus of elasticity of the material in which the stress measurements are made

γ - Poissons' ratio of the material in which the stress measurements are made

d - the diameter of the pilot hole

U_1, U_2, U_3 are the strains that have been measured on the three separate gauge axes.

The relationship between P, Q and θ are shown in Figure 2.

4.0 TEST RESULTS

The logs of borehole US-6 are contained in Appendix 1 and were compiled by the Civil Engineering and Architecture Department who also assumed the actual day to day supervision of the drilling operations while Civil Research Department personnel performed the actual stress measurements. The proposed and actual test locations are shown in Figure 3. The proposed test sites were chosen for engineering considerations, while the actual tests were done at depths where the rock was found to be solid enough for testing.

A total of six overcoring measurements were successfully carried out in borehole US-6. The results of these tests are given in Table 1, the test locations are given in Figure 2, the field test curves are given in Appendix 2 and the Young's Modulus test results are given in Appendix 3.

The secondary principal stress, P, ranged from 3.2 MPa (466 psi) to 21.12 MPa (3063 psi) while the secondary minor stress, Q, ranged from 0.30 MPa (50 psi) to 6.18 MPa (896 psi).

The ratio of P/Q varied from 1.89 to 10.7. There is a clustering of P orientations around the north direction (except test 5) as can be seen in Figure 4. The reason for the deviation of test 5 is not fully understood at the present time. Tests 1, 5 and 6 were performed near known joints and it is likely that the test results are probably influenced by them to some extent. The proximity of these joints, based on information contained in the drill core, to the test sites is shown in Figures 5, 6 and 7. It may be that in

this test area, the mass rock stress is controlled by the joint pattern more strongly than in other areas in southern Ontario where stress measurements have been made.

Two interesting items have come to light from these tests:

1. the P stress orientation is almost due north, whereas at other southern Ontario sites it is usually on the order of N40E to N60E.

2. the joints immediately below tests 5 and 6 appeared to be partially weathered and are probably partially open in situ as indicated by the existence of calcite crystals on the joint surfaces which could only grow in an open space.

Tests 2, 3 and 4 were made very close together because of the large magnitude of P and Q, where P = 21.12 MPa (3063 psi) and Q = 6.18 MPa (896 psi), in test 2. Test 2 was considered important because it is located very near the top corner of the proposed storage vault and the high in-situ stresses in turn might cause stability problems during construction. Test 3 was taken as close as possible to test 2, which in this case was 29 cm below test 2, in order to confirm the results of test 2. The P orientation of Test 3 is quite different from that of test 2 (166° as opposed to 029°) as were the stress magnitudes P = 4.89 MPa (709 psi) and Q = 2.56 MPa (371 psi). The results of test 3 did not confirm test 2 and so test 4 was performed 44 cm below test 3 and yielded results of P = 10.26 MPa (1488 psi), Q = 5.61 MPa (814 psi) with the azimuth of P is 000.

The reason for this variation in the stress field is not readily apparent. No joints or other structures were detected in the core, but this does not preclude the existence of some local structure such as a joint or vug at or near the edge of the borehole, which does not appear in the core. The proximity of such structures may cause a small, localized perturbation of the stress field.

5.0 CONCLUSION

High horizontal stresses were measured in borehole US-6 with the principal stress P in most cases being oriented toward North. The reason for and the significance of the variation between tests 2, 3 and 4 is not clearly understood at this time.

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Supervising Engineer
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DAM/JBW:kl

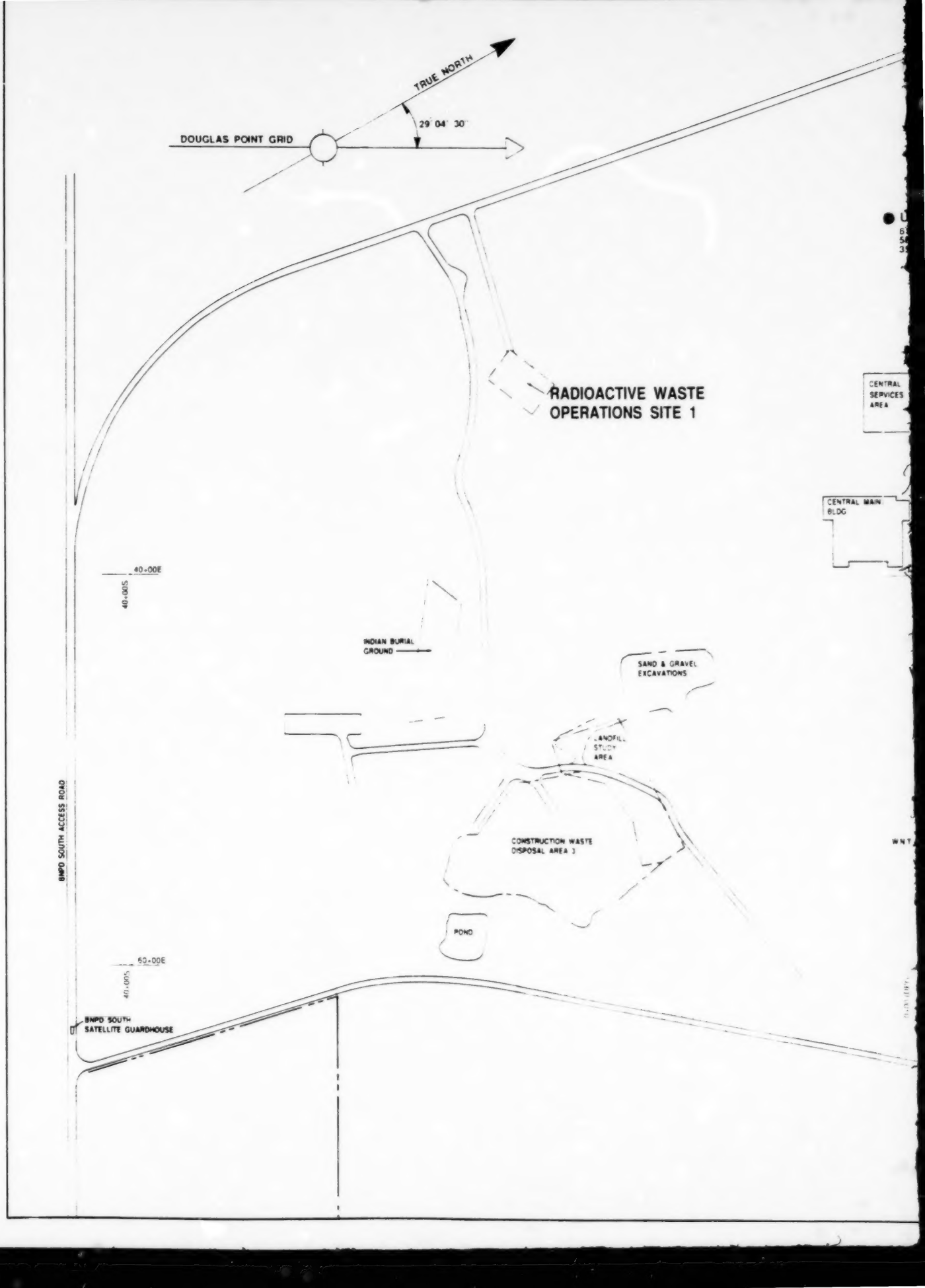
6.0 REFERENCES

1. McKay, D.A., "Bruce NGS "B" Stress Measurements Co-Operative Pilot Project", Civil Research Department Memorandum to Dr. C.F. Lee and Dr. T.W. Klym, File 844(T), July 28, 1988.

SUMMARY OF OVERCORE TESTS
BOREHOLE US-6 BRUCE NGS B, JUNE 1988

TEST	DEPTH FROM GROUND SURFACE		ELEV		ROCK TYPE	P		AZIMUTH OF P	Q		AVERAGE YOUNG'S MODULUS		P/Q
	FT	M	FT	M		psi	MPa		psi	MPa	x 10 psi	MPa	
1	136.16	41.50	493.23	150.33	MOTTLED DOLOSTONE	466	3.21	176	50	0.30	6.15	42424	10.7
2	178.88	54.52	450.51	137.31	CORAL	3063	21.12	029	896	6.18	6.00	41361	3.42
3	179.83	54.81	449.56	137.02	DOLOSTONE	709	4.89	166	371	2.56	9.66	66620	1.91
4	181.28	55.25	448.11	136.58	DOLOSTONE	1488	10.26	000	814	5.61	9.58	66047	1.89
5	204.60	62.36	424.79	129.47	CHERTY LIMESTONE	868	5.98	071	305	2.10	7.75	53414	2.85
6	208.15	63.44	421.24	128.39	CHERTY LIMESTONE	596	4.11	001	248	1.71	8.33	57411	3.74

TABLE 1


TRUE NORTH
29° 04' 30"
DOUGLAS POINT GRID
RADIOACTIVE WASTE
OPERATIONS SITE 1
CENTRAL
SERVICES
AREA
CENTRAL MAIN
BLDG
40+00E
40+00S
INDIAN BURIAL
GROUND
SAND & GRAVEL
EXCAVATIONS
LANDFILL
STUDY
AREA
CONSTRUCTION WASTE
DISPOSAL AREA 3
POND
BNPD SOUTH ACCESS ROAD
50+00E
40+00S
BNPD SOUTH
SATELLITE GUARDHOUSE

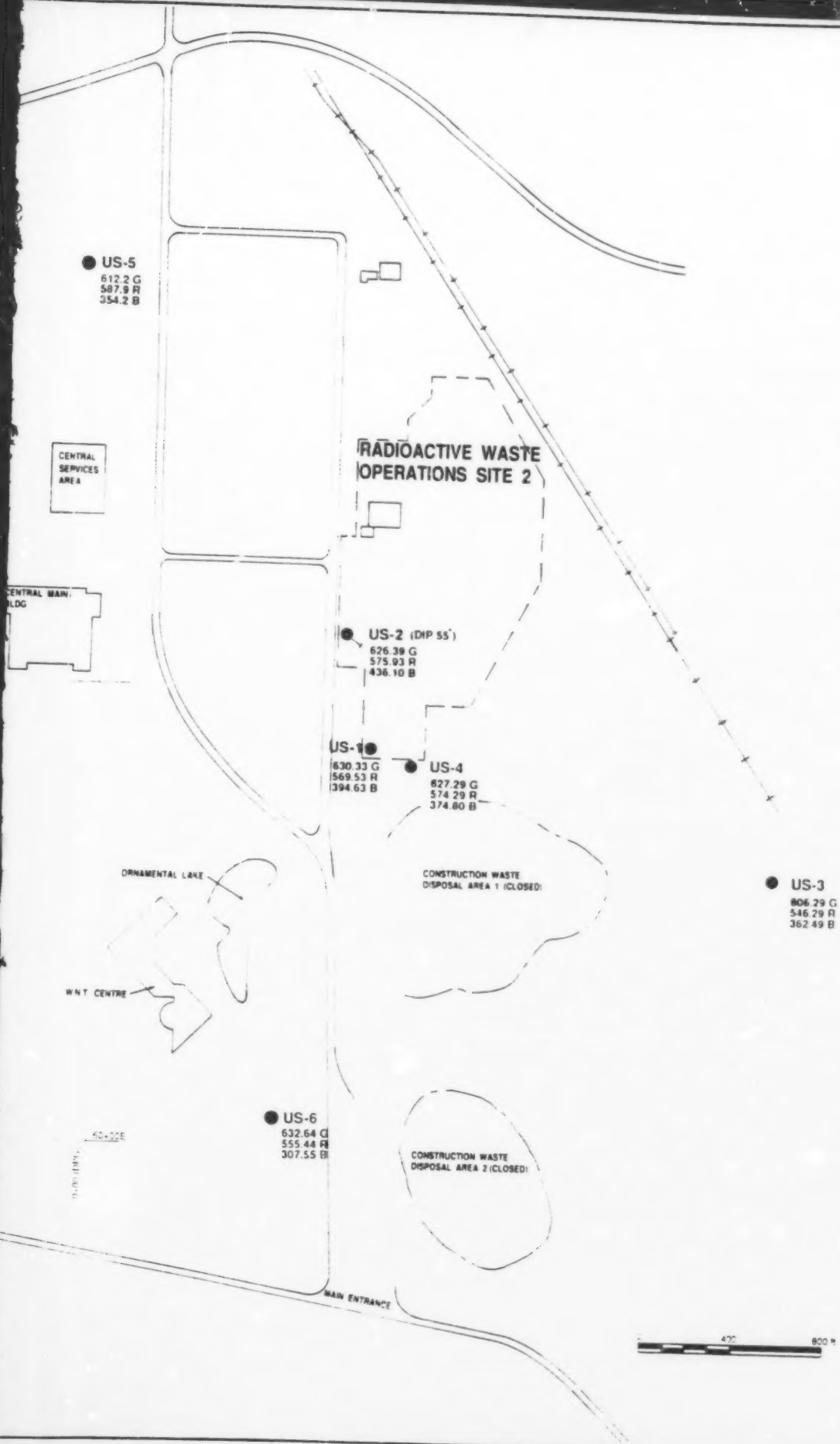


FIGURE 1

BNPD

PROPOSED UNDERGROUND IRRADIATED FUEL STORAGE FACILITIES

GEOLOGICAL INVESTIGATIONS 1986 1987

BOREHOLE LOCATION PLAN

Ontario Hydro

AS SHOWN

NK37 D3H 10120 0067 01

89-156

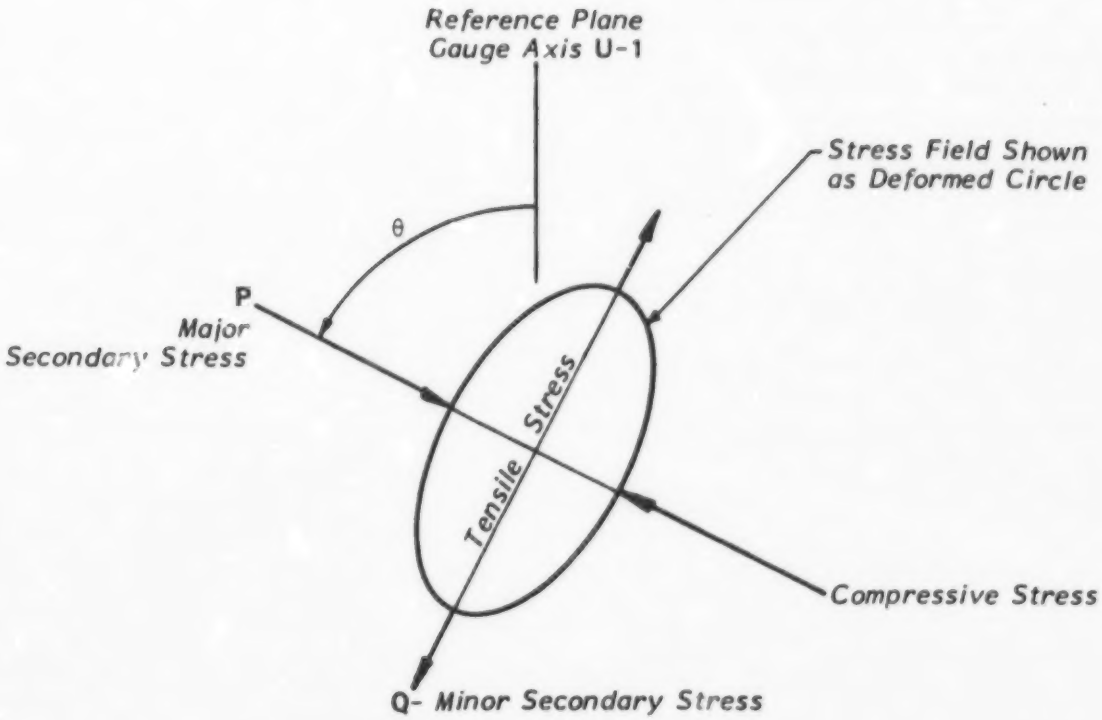


FIGURE 2

IN SITU STRESS MEASUREMENT TERMINOLOGY

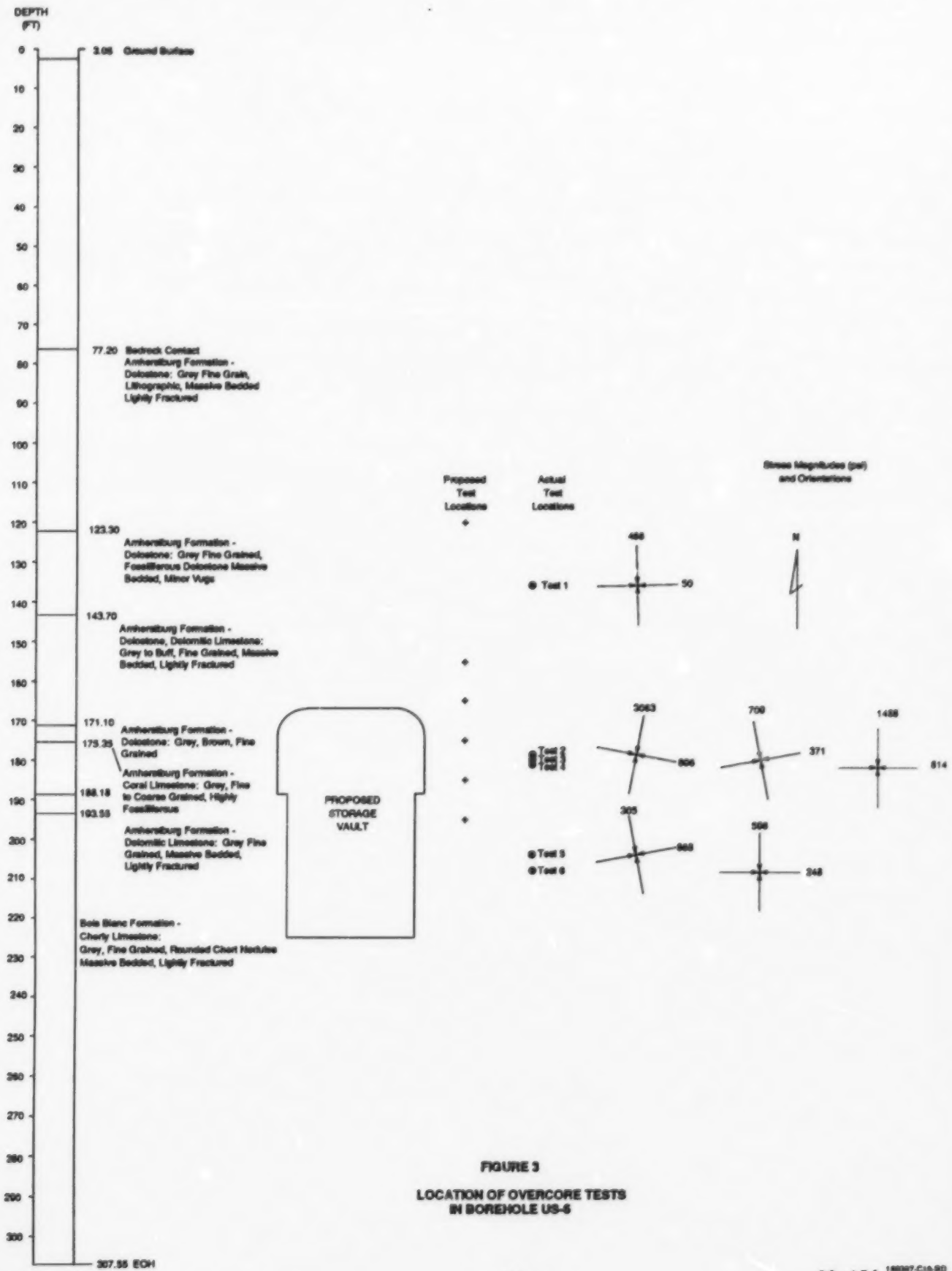


FIGURE 3

LOCATION OF OVERCORE TESTS IN BOREHOLE US-6

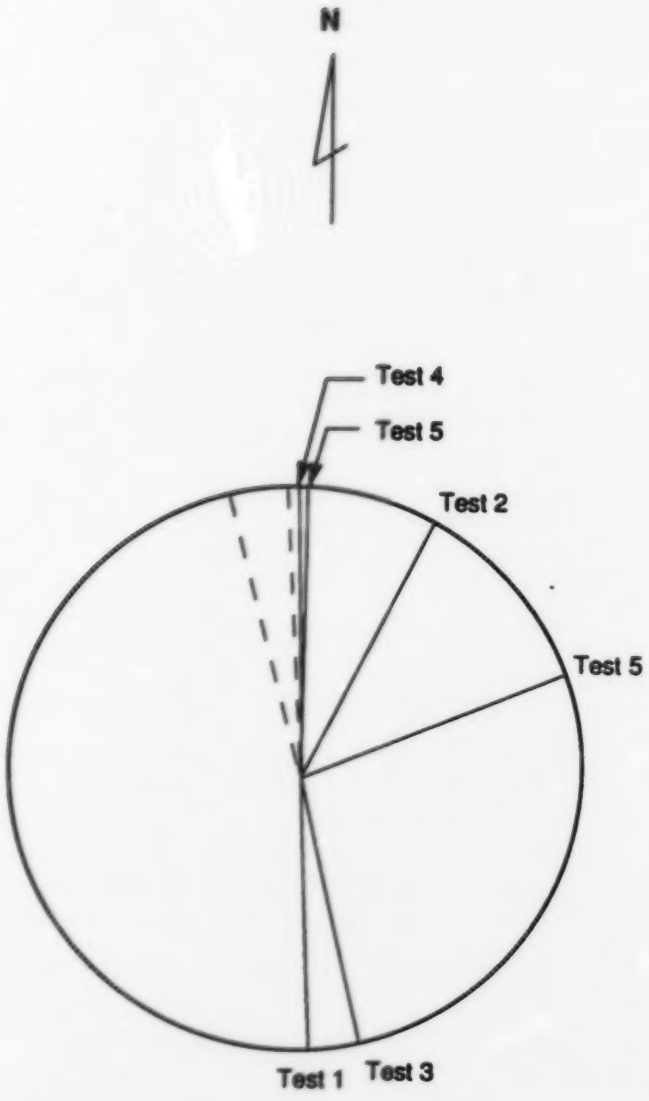


FIGURE 4

P STRESS ORIENTATIONS
BOREHOLE US 6
BRUCE B NGS
JUNE 1988

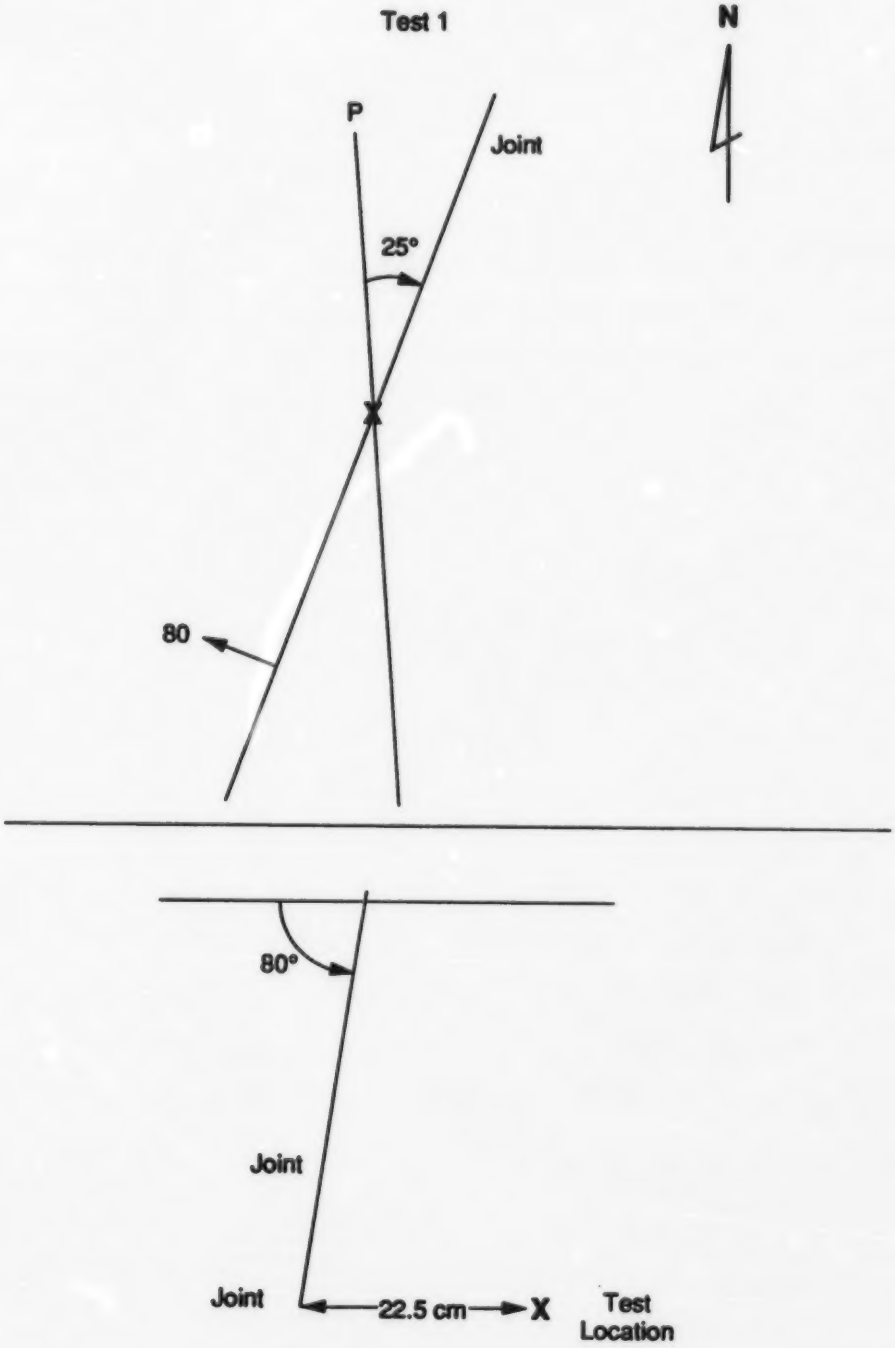


FIGURE 5

JOINT LOCATION WITH RESPECT TO TEST 1 LOCATION B.H. US-6, BRUCE NGS B

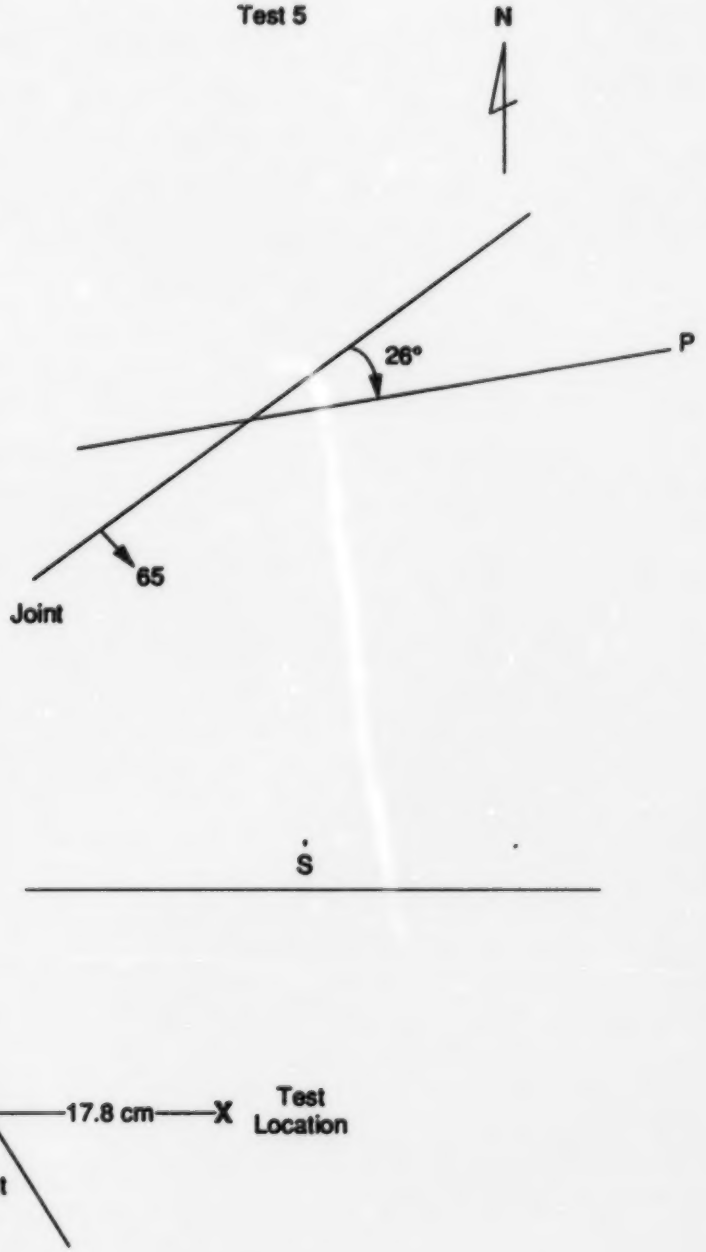


FIGURE 6

JOINT LOCATION WITH RESPECT TO TEST 5 LOCATION B.H. US-6, BRUCE NGS B

FIGURE 7

JOINT LOCATION WITH RESPECT TO TEST 6 LOCATION B.H. US-6, BRUCE NGS B

APPENDIX 1

BOREHOLE LOG

project: INFO UNDERGROUND NUCLEAR WASTE STORAGE
location: 0+100L, 0N+70E (OPG)
datum: COD
dip: 90°
bearing: —
hole type: ROTARY DIAMOND
hole size: HQ
drilled: 29 JUN-4 JUL 89
drawn: 27 JULY 89 GP
observer: R. Hamilton
compiled: J. Shaw
checked: JG,SC
approved: S. Lutwyk

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - m	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and casing	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psf type	shear strength psf results	special tests type	special tests results
	632.84				W.L.	DATUM - DRILL PLATFORM SURFACE										
2						West Bay PVC Casing (Datum El 632.15)										
4	629.59 3.05					Ground Surface										
6																
8																
10																
12																
14																
16																
18																
20						OVERBURDEN										
22																
24																
26																
28																
30																
32																
34																
36																
38																
40	592.84 40.00					CONTINUED ON SHEET 2 OF 8										

file name: bruce_us/008.xgs

Ontario Hydro
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geotechnical data sheet

hole no. US-8
fig.
sheet 1 OF 8

project: WNPD UNDERGROUND NUCLEAR WASTE STORAGE | hole type: ROTARY DIAMOND | observer: R. Hamilton
location: 6+125L 65+70E (UTM) | hole size: HQ | compiled: J. Gruza
dip: 90° | drilled: 29 JUN-4 JUL 89 | checked: JG,SC
datum: CGD | bearing: — | drawn: 27 JULY 89 GP | approved: B. Ladujic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - m	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and casing	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests: type	special tests: results	natural density lb/ft³	moisture content %	shear strength psf: type	shear strength psf: results	special tests: type	special tests: results
	592.84				W.R.	CONTINUED FROM SHEET 1 OF 8										
	40.00															
42																
44						West Bay Casing										
46																
48																
50																
52																
54																
56																
58						OVERBURDEN										
60																
62																
64																
66																
68																
70																
72																
74																
76						PW casing										
	565.44															
78	77.20					AMHERSTBURG FORMATION										
				26		DOLOSTONE: ground core										
80					100%	(For Description See Sheet 3 of 8)										
				22												
82	560.84															
	82.00					CONTINUED ON SHEET 3 OF 8										
						See Sheet 3										

file name: bruce_us/006s2.rgs

Ontario Hydro
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Civil Engineering & Architecture Dept

geotechnical data sheet

hole no. US-6 | fig.
sheet 2 OF 8

project: BNPD UNDERGROUND NUCLEAR WASTE STORAGE | hole type: ROTARY DIAMOND | observer: R. Hermier
location: 8+18N, 86.78E (DPD) | hole dia: HQ | compiled: J. Grass
dip: 90° | drilled: 29 JUN-4 JUL 89 | checked: JG,EC
datum: CGD | bearing: —— | drawn: 28 JULY 89 GP | approved: B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - m	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and casing	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psf type	shear strength psf results	special tests type	special tests results
	560.84				W.R.	CONTINUED FROM SHEET 2 OF 8										
	82.00					AMHERSTBURG FORMATION DOLOSTONE: grey, fine grained to lithographic, massive bedded, lightly fractured										
84				22				2.7 E-6								
86						HW casing										
88						West Bay Casing										
90						86.67-88.8 ft. vuggy open limestone (lost water)										
92					100%	88.8-104.0 ft. moderately to highly fractured										
94				12		ground core		No Test See Note 2								
96																
98						ground core										
100																
102				31		102.9-103.61 ft. possible water loss										
104						ground core										
106								8.8 E-2								
108																
110					50%	109.9-111.7 ft. finely laminated limestone										
112																
114				51												
116								0.20 E-2								
118						116.2-118.9 ft. dark brown, porous, vuggy, limestone											
118						ground core										
120																
122	510.84															
	122.00					CONTINUED ON SHEET 4 OF 8										
						See Sheet 4										

file name: bruce_us/006s3.ugs

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Civil Engineering & Architecture Dept

geotechnical data sheet

hole no. US-6 | fig.
sheet 3 OF 8

89-156

project: INWD UNDERGROUND NUCLEAR WASTE STORAGE | hole type: ROTARY DIAMOND | observer: R. Hensler
location: 6+139N, 98.78E (DPG) | hole size: HQ | compiled: J. Gruss
dip: 90° | drilled: 30 JUN-4 JUL 88 | checked: JG,EC
datum: CGD | bearing: — | drawn: 28 JULY 88 GP | approved: B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and casing	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psf type	shear strength psf results	special tests type	special tests results
	512.84				W.R.	CONTINUED FROM SHEET 3 OF 8										
	511.34					(For Description See Sheet 3)										
124	123.30			51		AMHERSTBURG FORMATION DOLOSTONE: grey, fine grained, fossiliferous, massive bedded, minor vugs											
						ground core										
126																
128						West Bay Casing		1.2 0.2								
130					50%											
132				92												
134								NR 0.3								
136						- 136.18 ft. U.S.B.M. overcoring stress test											
138						88.0-137.4 ft. - (See Note 3)											
				100				NR 0.3								
140						packer										
142																
144	490.94 143.70					AMHERSTBURG FORMATION DOLOSTONE, DOLOMITIC LIMESTONE: grey to buff, fine grained, massive bedded, lightly fractured											
146																
148								0.2 0.3								
				86	100%											
150																
152																
154						pumping port #8										
156						154.4-158.3 ft. vuggy limestone		24 0.3								
158				79												
160	474.84 160.00					CONTINUED ON SHEET 5 OF 8										

file name: bruce_us/006e4.ugs

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Civil Engineering & Architecture Dept

geotechnical data sheet

hole no. US-8 | fig.
sheet 4 OF 8

project: SNPD UNDERGROUND NUCLEAR WASTE STORAGE | hole type: ROTARY DIAMOND | observer: R. Herntier
location: 8+15N, 88.78E (DP-5) | hole size: HQ | compiled: J. Grass
dip: 90° | drilled: 30 JUN-4 JUL 89 | checked: JG,EC
datum: CGD | bearing: — | datum: 28 JULY 89 GP | approved: B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	"N" value per ft / RQD %	water level and caving	description / remarks	observation well data	"k" soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	472.84				W.R.	CONTINUED FROM SHEET 4 OF 8										
162	160.00					AMHERSTBURG FORMATION DOLOSTONE, DOLOMITIC LIMESTONE: grey to buff, fine grained, massive bedded, lightly fractured		24 8.5								
164						pressure port #6										
166						West Bay Casing										
168				79				Nil 8.5								
170																
172	481.54 171.10					ANMHERSTBURG FORMATION DOLOSTONE: grey, brown, fine grained, finely laminated with bituminous layers at 171.0-172.5 ft.										
174						packer										
176	457.29 175.35					ground core ground core ground core AMHERSTBURG FORMATION CORAL LIMESTONE: grey, fine to coarse grained, highly fossiliferous, massive bedded, lightly fractured										
178						- 178.88 ft. U.S.B.M. overcoring stress test										
180				100	100%	- 179.83 ft. U.S.B.M. overcoring stress test ground core		Nil 8.5								
182						- 181.28 ft. U.S.B.M. overcoring stress test										
184																
186																
188	444.46 188.18					pumping port #5										
190						AMHERSTBURG FORMATION DOLOMITIC LIMESTONE: grey, fine grained, massive bedded, lightly fractured		0.8 8.5								
192				43												
194	439.09 193.55					BOIS BLANC FORMATION CHERTY LIMESTONE: grey, fine grained, rounded chert nodules, massive bedded, lightly fractured										
196								0.2 8.5								
198						Pressure Port #6										
200	432.64 200.00			88		199.6-199.8 ft. vuggy packer CONTINUED ON SHEET 6 OF 8										

file name: bruce_us/006s5.ugs+006s5l

Ontario Hydro
Design & Construction Branch
Civil Engineering & Architecture Dept

geotechnical data sheet

hole no. US-8 | fig.
sheet 5 OF 8

project	INPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND	observer	R. Herzler
location	6x12N, 66.79E (DPD)	hole size	HQ	compiled	J. Grass
	dip 89°	drilled	29 JUN-4 JUL 89	checked	JG,EC
datum	CGD	bearing —	drawn	28 JULY 89 GP	approved	B. Lukajic

borehole data | **borehole log** | **water inf.** | **field tests** | **laboratory tests**

scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and casing	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests: type	special tests: results	natural density lb/ft³	moisture content %	shear strength psf: type	shear strength psf: results	special tests: type	special tests: results
	432.84				W.R.	CONTINUED FROM SHEET 5 OF 8										
	200.00					AMHERSTBURG FORMATION CHERTY LIMESTONE: grey, fine grained, rounded chert nodules, massive bedded, lightly fractured	packer									
202								0.2 ft/s								
204				88		pumping port #4 203.6-204.8 ft. possible open bedding seam 204.2-204.4 ft. vuggy										
206						West Bay Casing										
208								1.2 ft/s								
210				100												
212						ground core pressure port #4										
214						214.1, 214.2, 214.3 ft. - bituminous coated bedding planes										
216							packer									
218								7.8 ft/s								
220				90	100%											
222																
224																
226																
228								24 ft/s								
230																
232						pumping port #3										
234				85												
236																
						pressure port #3		Nil ft/s								
238						- 237.8 ft. drill water loss										
240	392.84				0%											
	240.00					CONTINUED ON SHEET 7 OF 8										

file name: bruce_us\006s6.ugs+006s6l

Ontario Hydro
Design & Construction Branch
Civil Engineering & Architecture Dept

geotechnical data sheet

hole no. US-6 | fig.
sheet 6 OF 8

project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND	observer	R. Hamilton
location	0+183, 88.7RE (DPD)	hole size	HQ	compiled	J. Grass
	dip 90°	drilled	29 JUN-4 JUL 89	checked	JG,EC
datum	CGD	bearing —	drawn	28 JULY 89 GP	approved	S. Lukajic

borehole data							borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and casing		description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psf type	shear strength psf results	special tests type	special tests results
	382.84				W.R.		CONTINUED FROM SHEET 6 OF 8										
	240.00																
242							packer		Nil 0.5								
244				85													
246							West Bay Casing										
248									Nil 0.5								
250							BOIS BLANC FORMATION CHERTY LIMESTONE: grey, fine grained, massive bedded, lightly fractured, chert nodules throughout										
252																	
254																	
256							pumping port #2										
258									0.3 0.5								
260					0%												
262				98			282.6-282.7 ft. shaly layers										
264																	
266							pressure port #2										
268																	
270							269.15 ft. soft, bituminous seam (1/8" thick)		Nil 0.5								
272							packer										
274																	
276							pressure port #1										
278									Nil 0.5								
280	352.84			96			pumping port #1										
	280.00						CONTINUED ON SHEET 8 OF 8										

file name: bruce_us/006a7.ugs+006a7f

Ontario Hydro
Design & Construction Branch
Civil Engineering & Architecture Dept

geotechnical data sheet

hole no. US-6 | fig.
sheet 7 OF 8

project: BNPD UNDERGROUND NUCLEAR WASTE STORAGE | hole type: ROTARY DIAMOND | observer: R. Haridar
location: 6+139N, 68.79E (DPD) | hole size: HQ | sampled: J. Gross
dip: 90° | drilled: 30 JUN-4 JUL 89 | checked: JQ,EC
datum: CGD | bearing: — | drawn: 30 JULY 89 GP | approved: B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests: type	special tests: results	natural density lb/ft³	moisture content %	shear strength psf: type	shear strength psf: results	special tests: type	special tests: results
	352.84				W.R.	CONTINUED FROM SHEET 7 OF 8										
282	280.00							HI 8.5								
284																
286																
288								HI 8.5								
290						End Cap (El 289.33)										
292						BOIS BLANC FORMATION CHERTY LIMESTONE: grey, fine grained, massive bedded, lightly fractured, chert nodules throughout, thin shaly layers throughout										
294				98												
296																
298								1-7 8.5								
300						300.3-300.4 ft. possible open bedding seams (water loss)											
302																
304																
306								HI 8.5								
308	325.09 327.55					END OF BOREHOLE C.R. 97 %										

NOTES:
1. All geological contacts are approximate
2. No water test due to loose rock and caving conditions 89.7 - 100.95 ft
3. Ran PW casing to 77.2 ft, HW casing to 80.15 and 88.5 ft
4. Poor rock conditions grouted from 137.4 ft to 88.0 ft
5. U.S.B.M. overcoring insitu stress measurements taken July, 1988 by Civil Research Division
6. For details of structural features see Log of Discontinuities
7. West Bay Multi-Level Casing installed Nov, 1988
8. Water pressure test performed using constant head method

file name: bruce_us/006s8.ugs

Ontario Hydro
Design & Construction Branch
Civil Engineering & Architecture Dept

geotechnical data sheet

hole no. US-6 | fig.
sheet 8 OF 8

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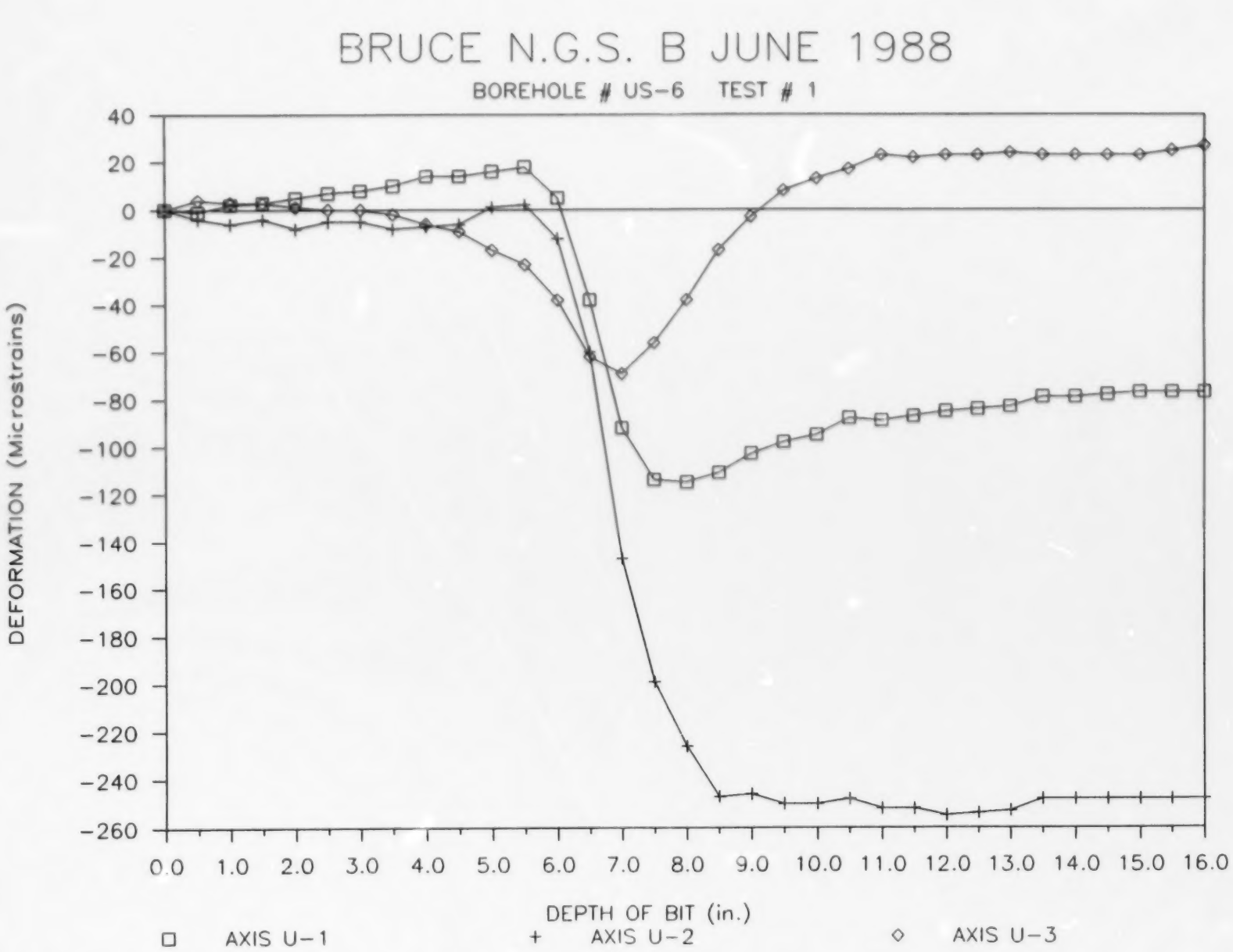
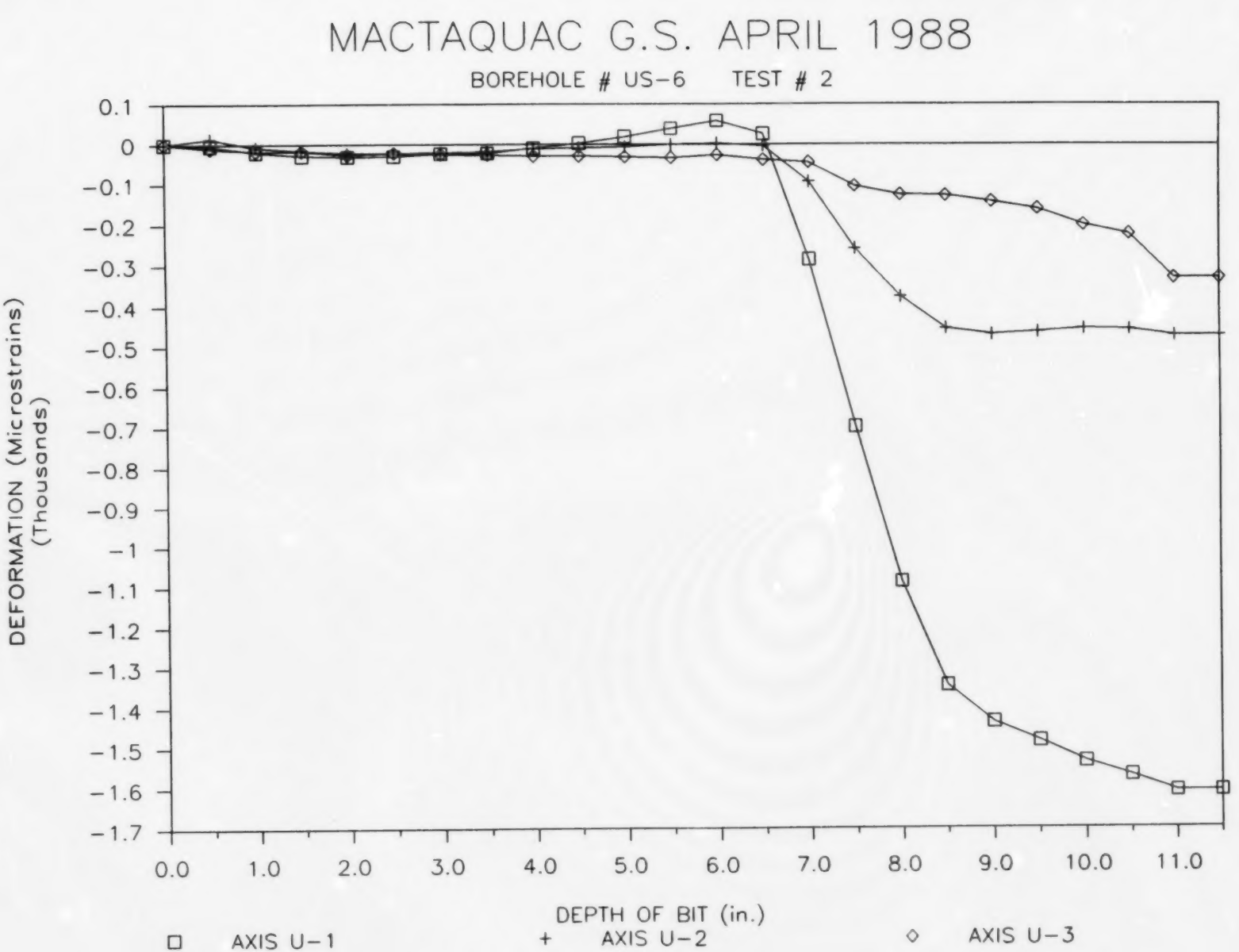
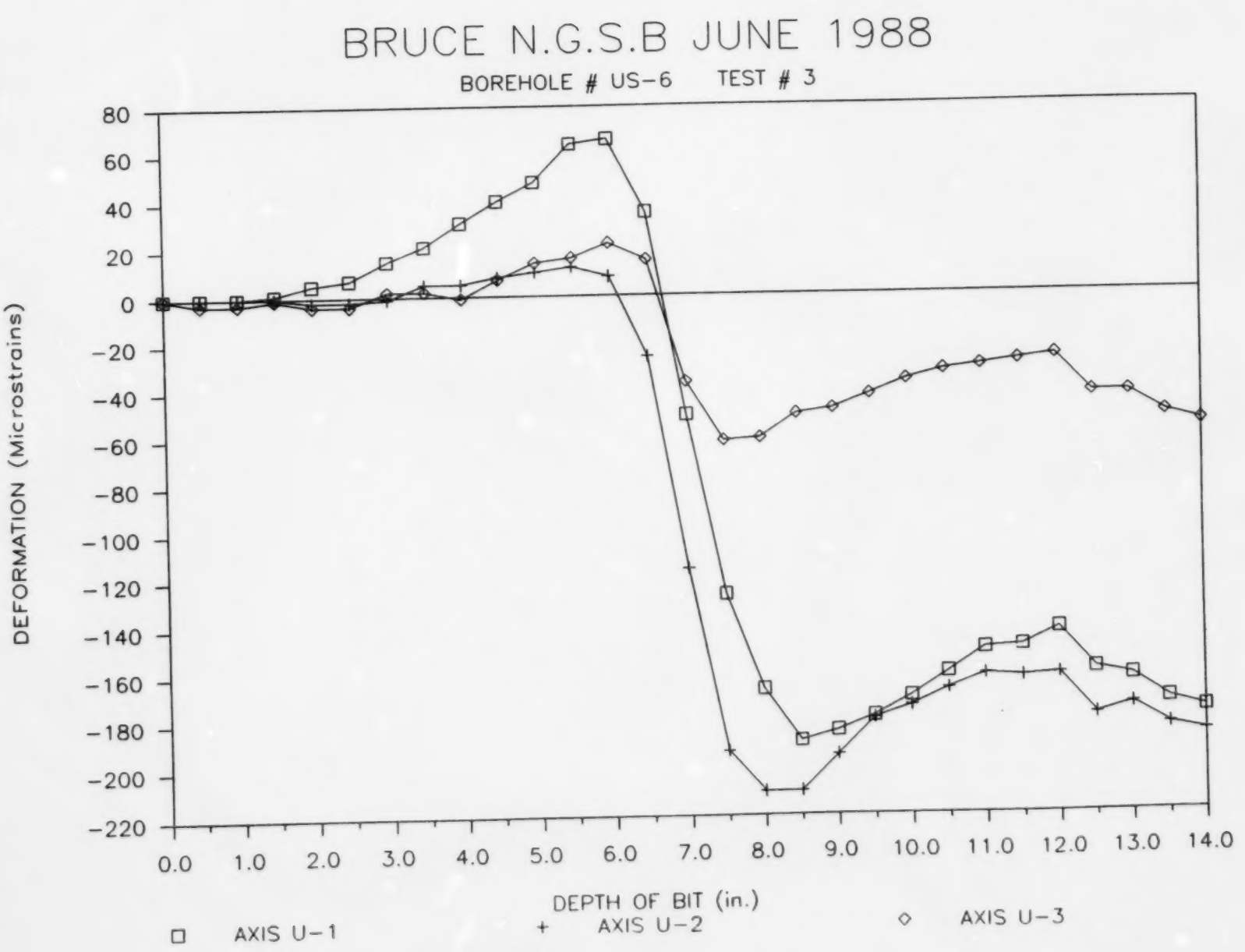
APPENDIX 2

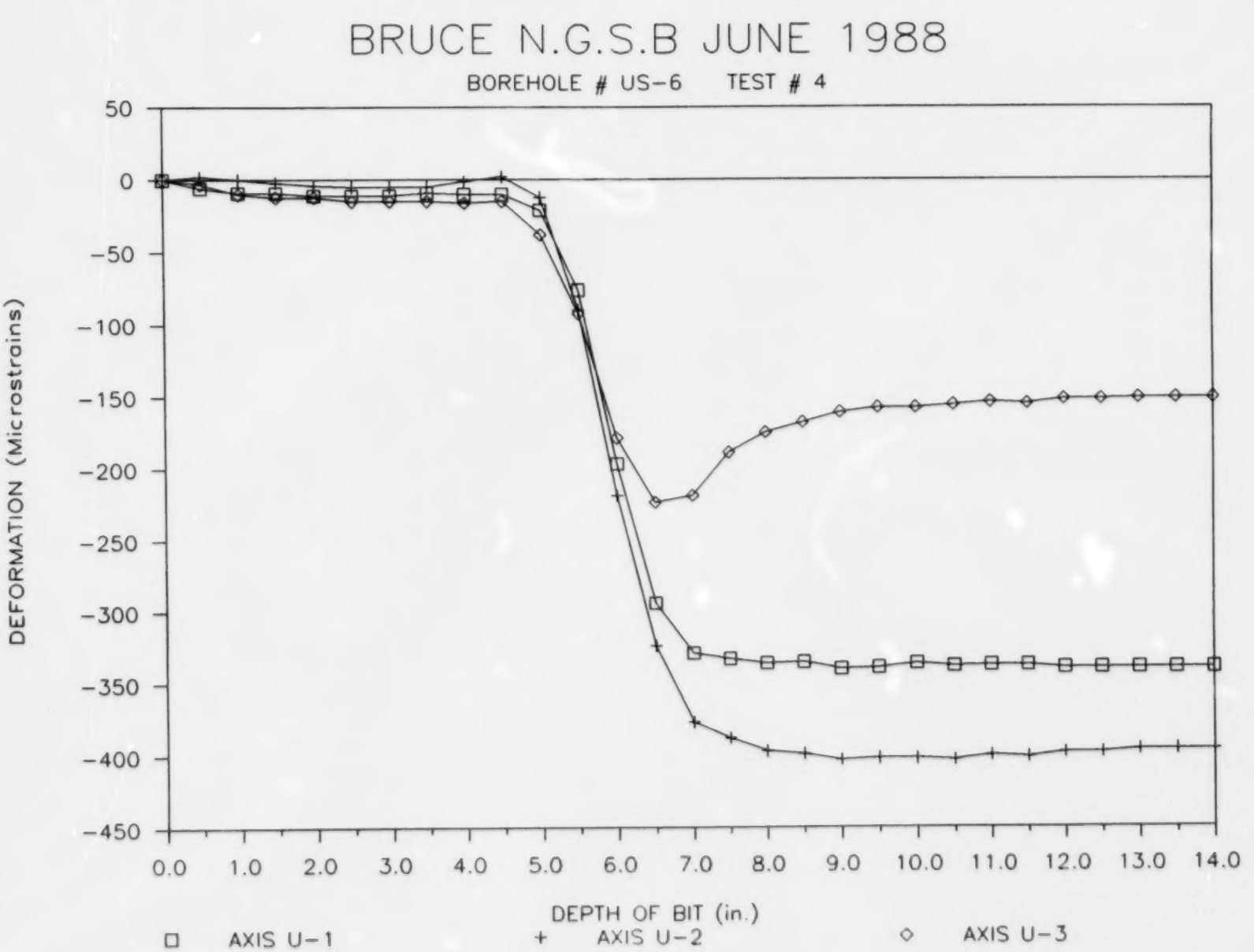
FIELD TEST CURVES

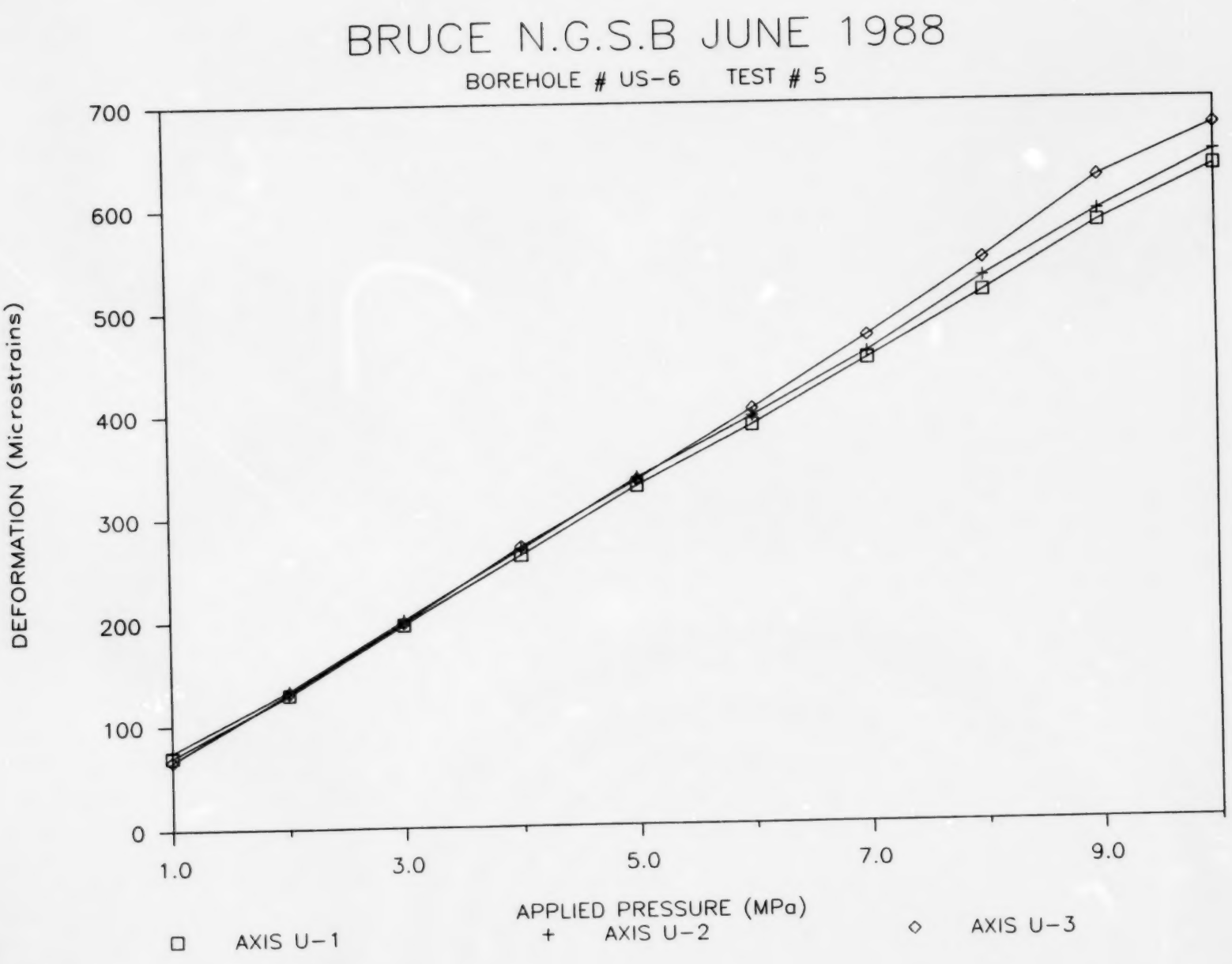

BRUCE N.G.S. B JUNE 1988
BOREHOLE # US-6 TEST # 1
DEFORMATION (Microstrains)
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0
DEPTH OF BIT (in.)
AXIS U-1
AXIS U-2
AXIS U-3

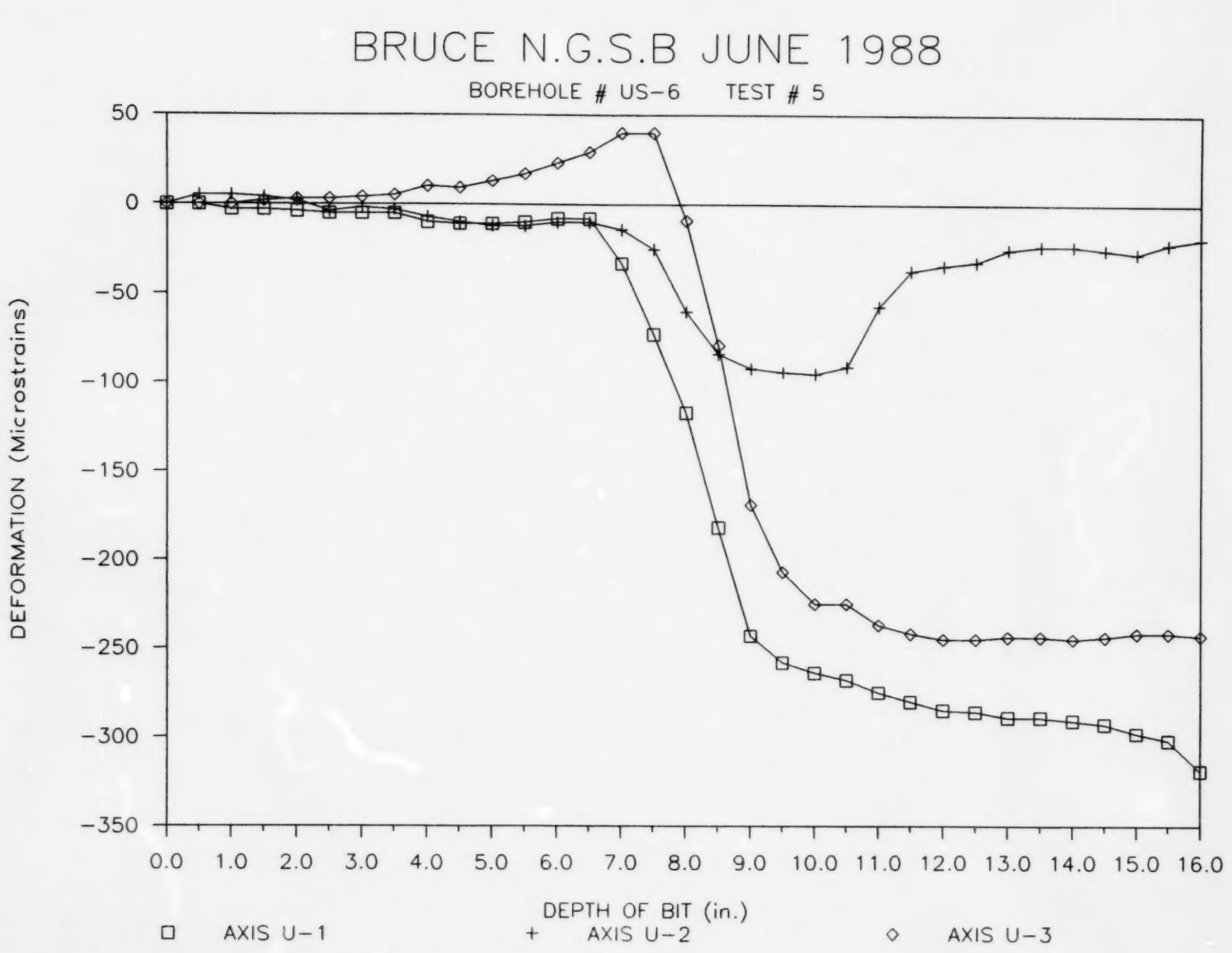
89-156


MACTAQUAC G.S. APRIL 1988
BOREHOLE # US-6 TEST # 2
DEFORMATION (Microstrains)
(Thousands)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3
-1.4
-1.5
-1.6
-1.7
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
DEPTH OF BIT (in.)
AXIS U-1
AXIS U-2
AXIS U-3


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 3
DEFORMATION (Microstrains)
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
DEPTH OF BIT (in.)
AXIS U-1
AXIS U-2
AXIS U-3


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 4
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
DEFORMATION (Microstrains)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
DEPTH OF BIT (in.)
AXIS U-1
AXIS U-2
AXIS U-3


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 5
DEFORMATION (Microstrains)
700
600
500
400
300
200
100
0
1.0
3.0
5.0
7.0
9.0
APPLIED PRESSURE (MPa)
□ AXIS U-1
+ AXIS U-2
◇ AXIS U-3


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 5
DEFORMATION (Microstrains)
50
0
-50
-100
-150
-200
-250
-300
-350
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0
DEPTH OF BIT (in.)
AXIS U-1
AXIS U-2
AXIS U-3

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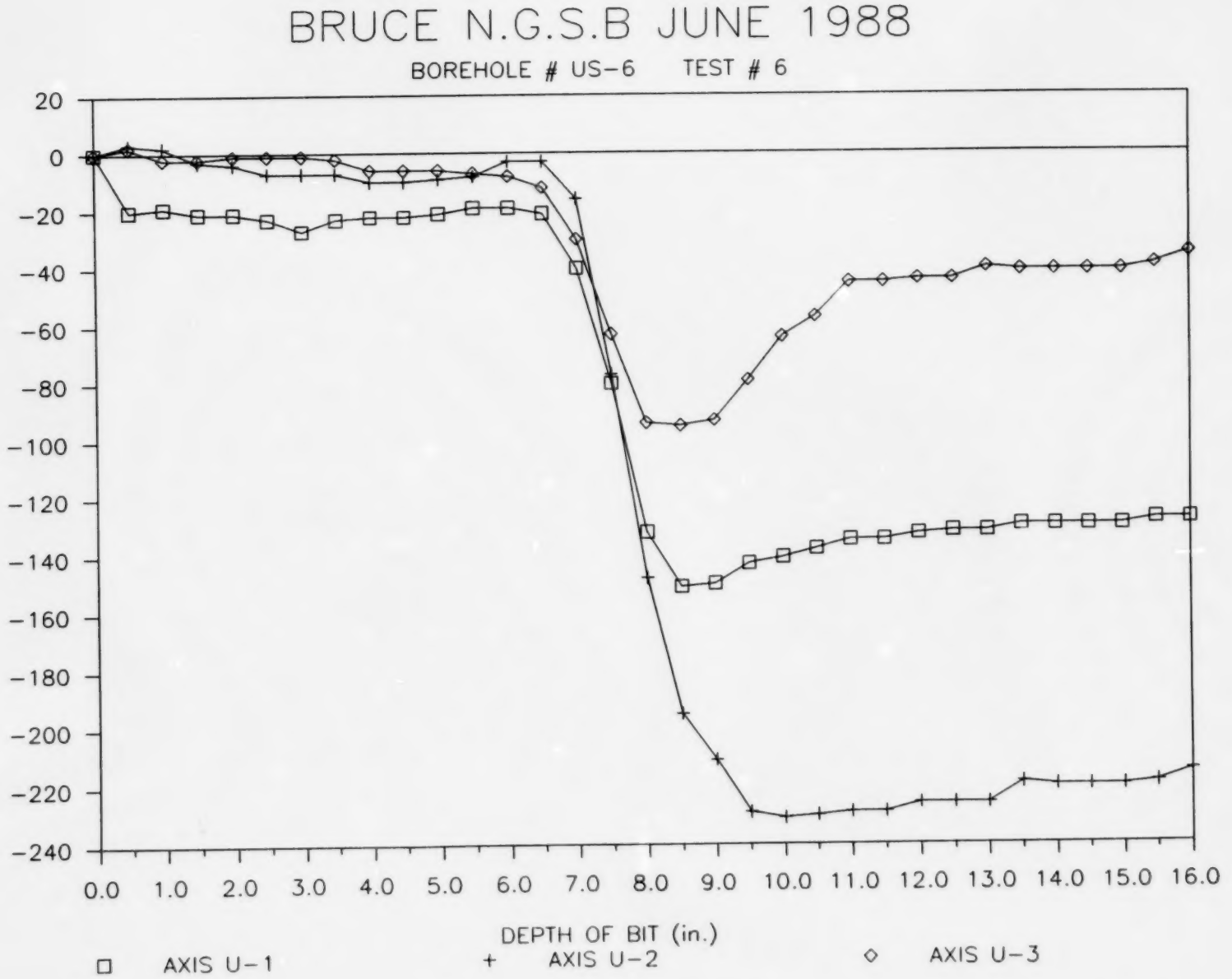
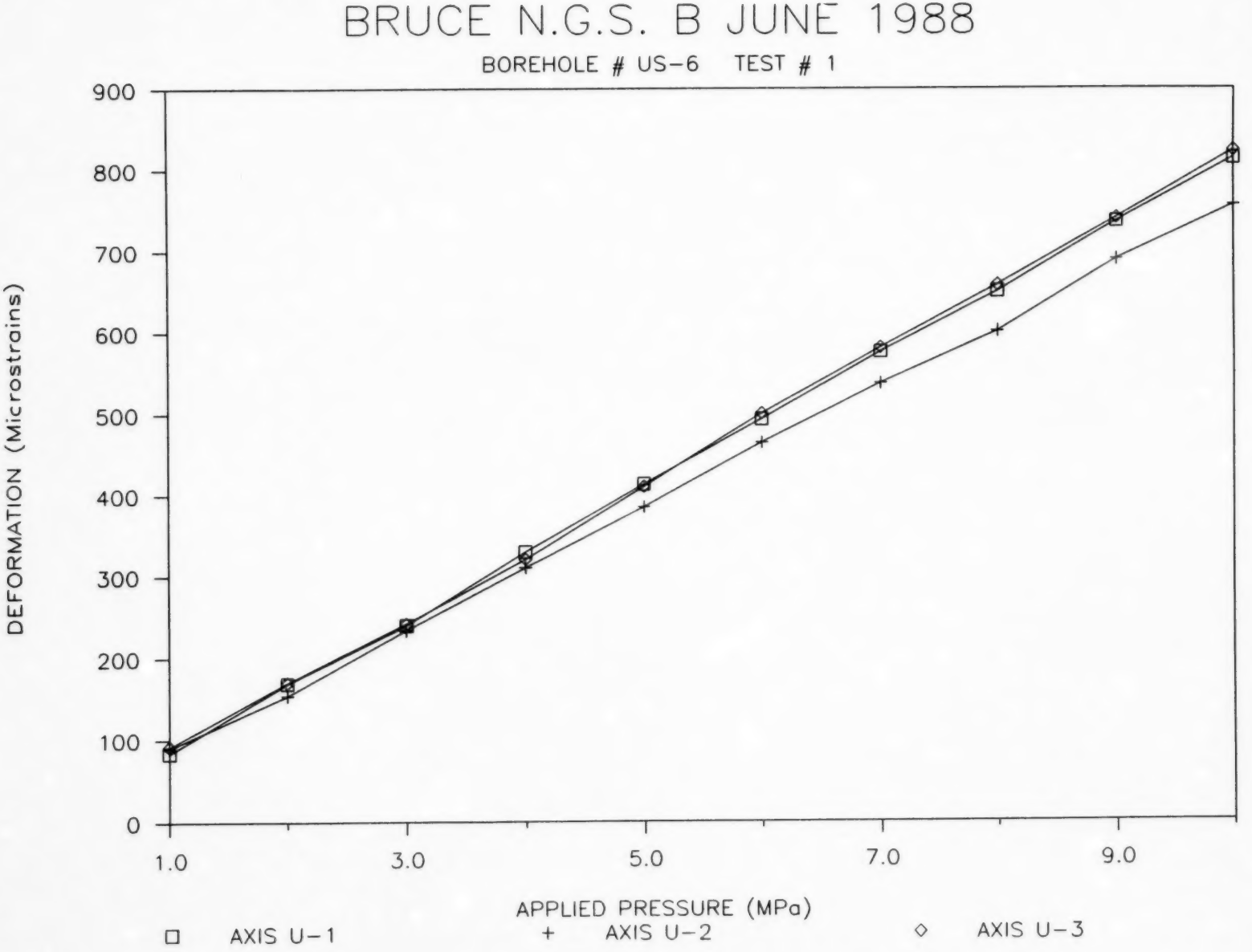
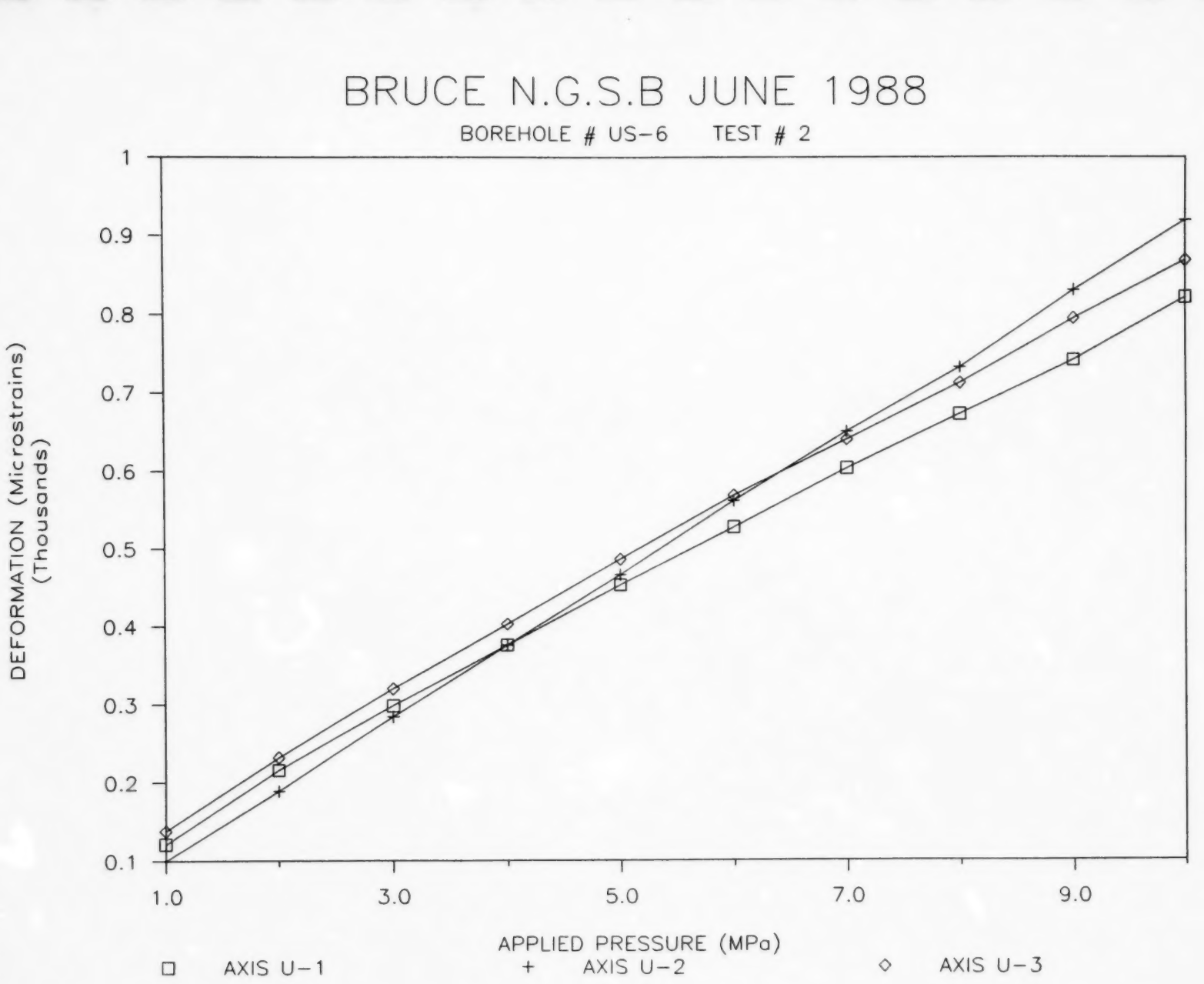

BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 6
DEFORMATION (Microstrains)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0
DEPTH OF BIT (in.)
AXIS U-1
AXIS U-2
AXIS U-3

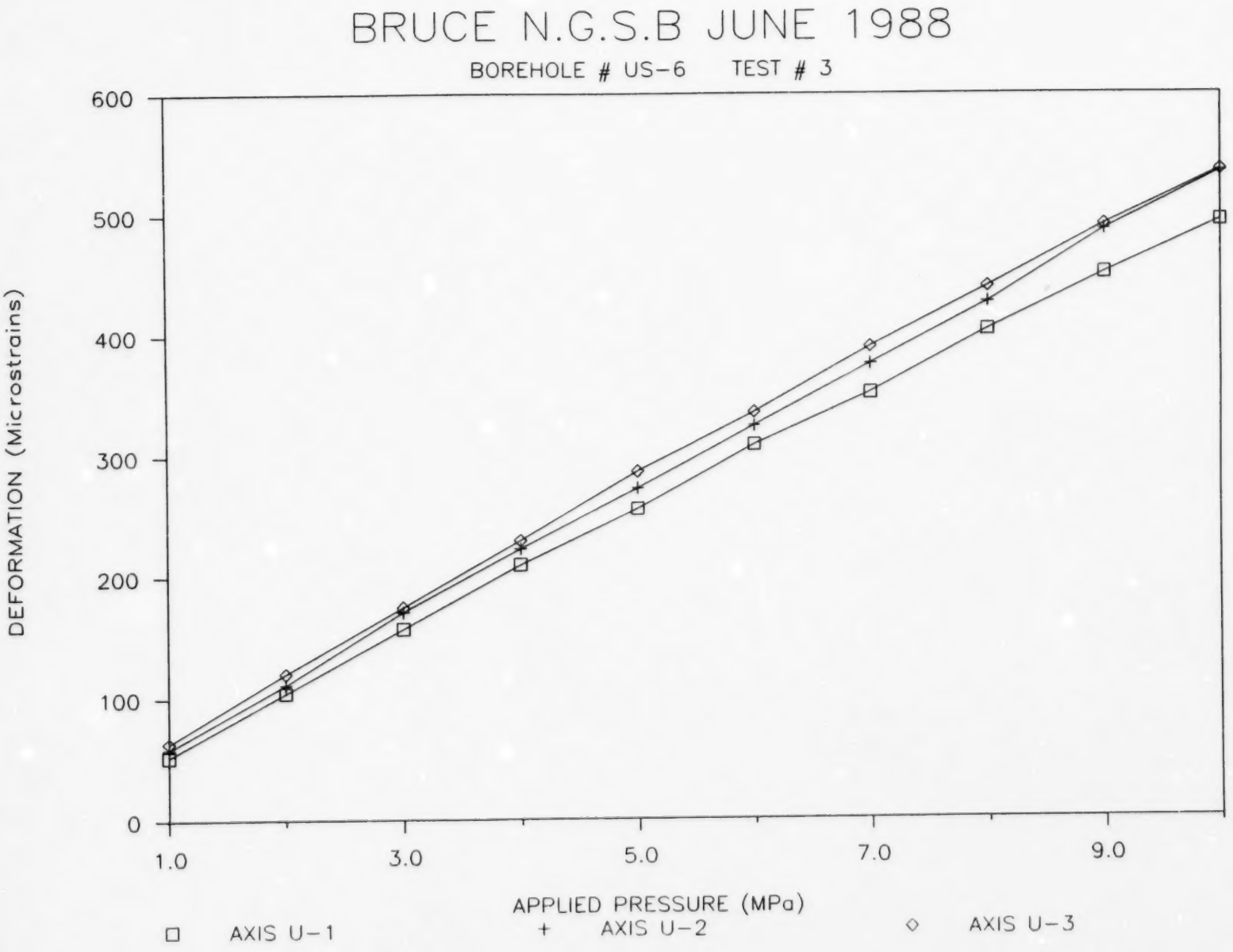
APPENDIX 3

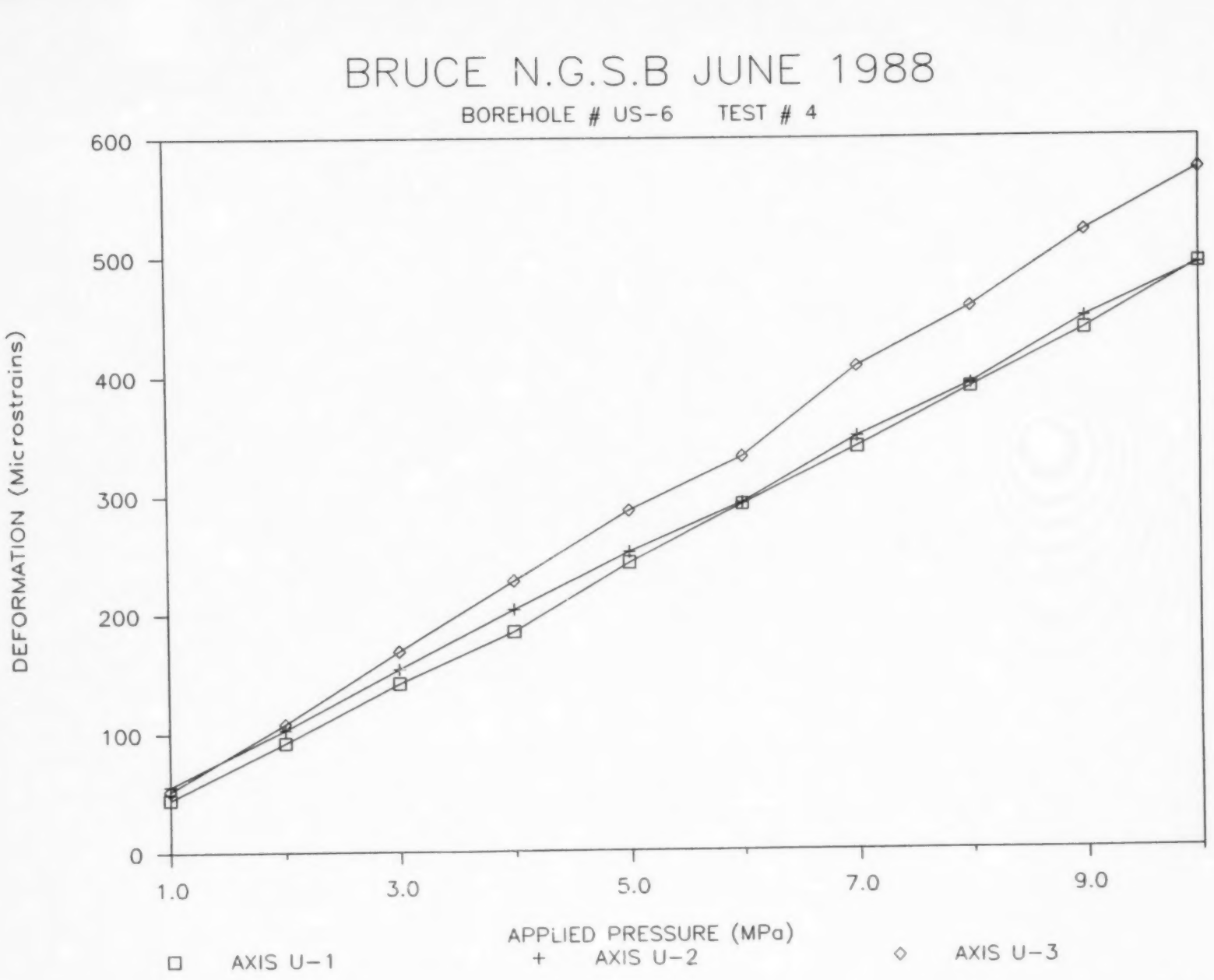
YOUNG'S MODULUS TEST RESULTS

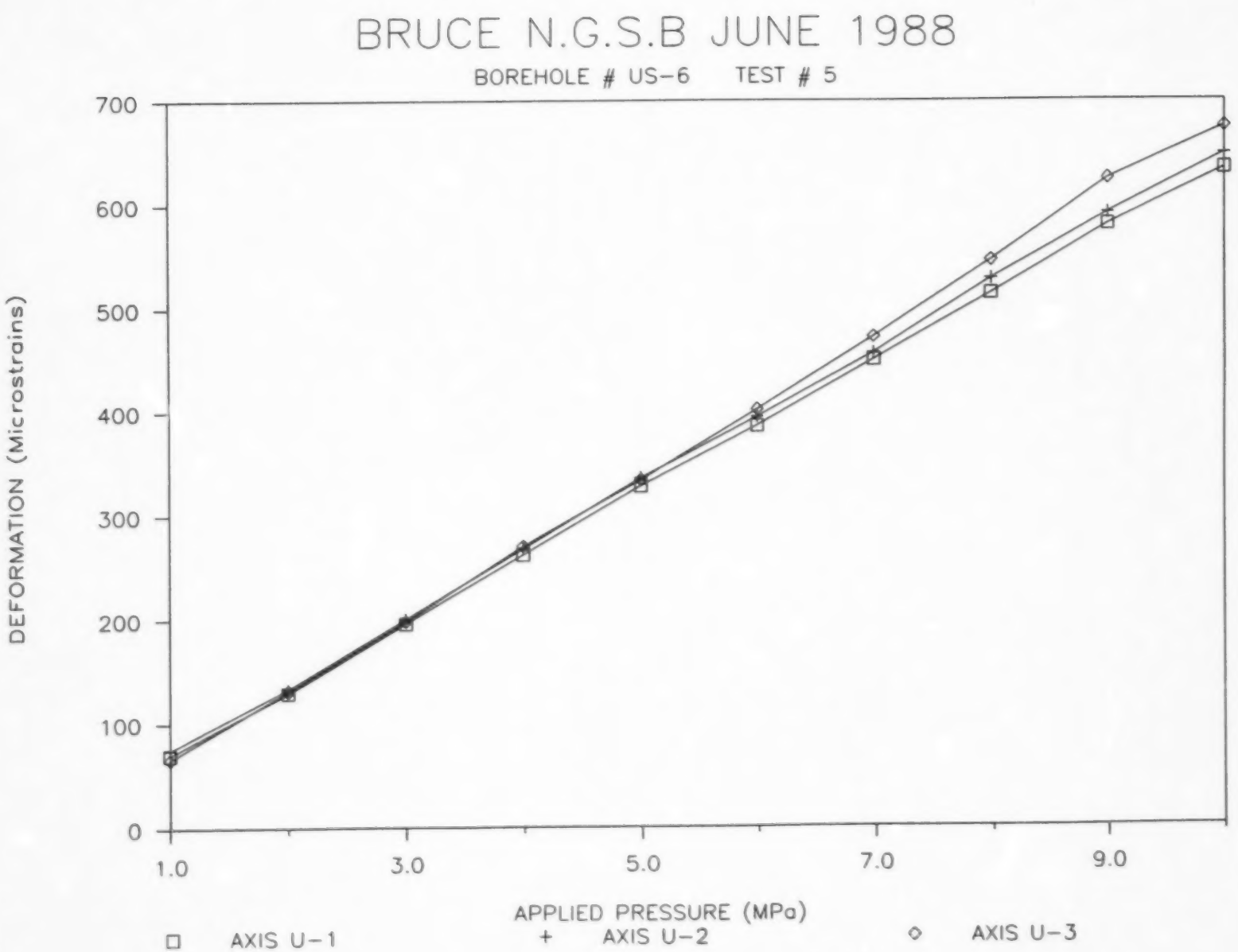

BRUCE N.G.S. B JUNE 1988
BOREHOLE # US-6 TEST # 1
DEFORMATION (Microstrains)
900
800
700
600
500
400
300
200
100
0
1.0
3.0
5.0
7.0
9.0
APPLIED PRESSURE (MPa)
AXIS U-1
AXIS U-2
AXIS U-3

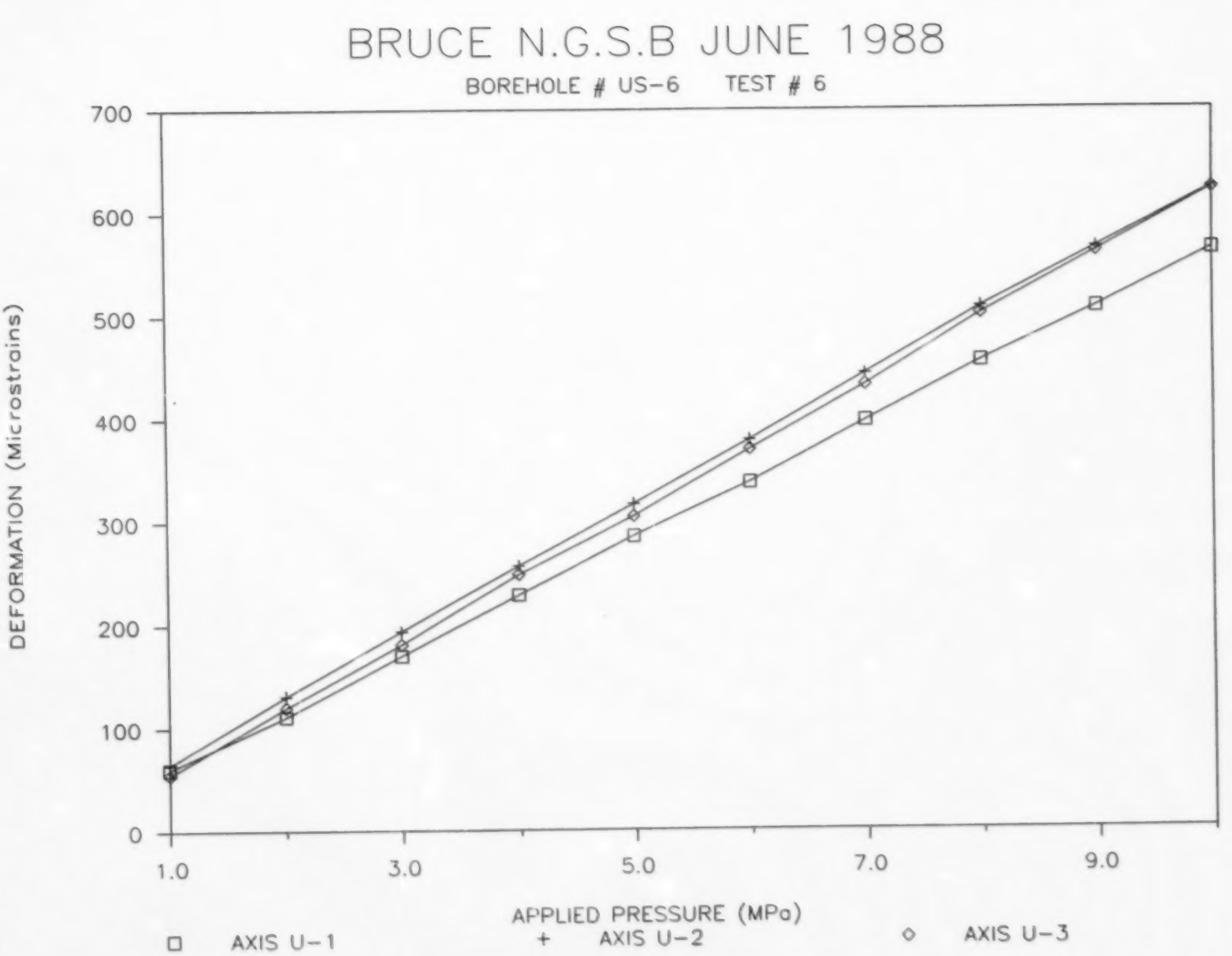

BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 2
DEFORMATION (Microstrains)
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1.0
3.0
5.0
7.0
9.0
APPLIED PRESSURE (MPa)
□ AXIS U-1
+ AXIS U-2
◇ AXIS U-3

89-156


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 3
600
500
400
300
200
100
0
DEFORMATION (Microstrains)
1.0
3.0
5.0
7.0
9.0
APPLIED PRESSURE (MPa)
AXIS U-1
AXIS U-2
AXIS U-3


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 4
600
500
400
300
200
100
0
1.0
3.0
5.0
7.0
9.0
DEFORMATION (Microstrains)
APPLIED PRESSURE (MPa)
AXIS U-1
AXIS U-2
AXIS U-3


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 5
DEFORMATION (Microstrains)
700
600
500
400
300
200
100
0
1.0
3.0
5.0
7.0
9.0
APPLIED PRESSURE (MPa)
AXIS U-1
AXIS U-2
AXIS U-3


BRUCE N.G.S.B JUNE 1988
BOREHOLE # US-6 TEST # 6
700
600
500
400
300
200
100
0
1.0
3.0
5.0
7.0
9.0
DEFORMATION (Microstrains)
APPLIED PRESSURE (MPa)
AXIS U-1
AXIS U-2
AXIS U-3

89-156